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OAR RESEARCH REVIEW
OFFICE of AEROSPACE RESEARCH

OAR:
The Basic Research Agency
of The United States Air Force

VOLUME II NUMBER 23 10 FEBRUARY 1964

deep-sea seismic monitors

Major ROBERT A. GRAY, USAF, *Terrestrial Sciences Laboratory*, AFCRL

Since midsummer, AFCRL has conducted a series of studies in the Pacific on deep-sea seismometers and seismometer techniques. These tests took place off the California coast, near the Aleutian Islands, and in the Hawaiian area. These tests have three aspects: to develop methods for detecting underground nuclear detonations, to gather general information on seismological characteristics of the ocean bottom and, last, to improve underwater seismological devices.

The deep-sea seismology program is a part of the larger AFCRL VELA-UNIFORM Program. The most crucial element in the seismic detection and identification of underground explosions is the discrimination between signals generated by these explosions and those resulting from natural seismic activity. Due to the diversity of earth materials, much of the character of a seismic signal received at a distant point is that imposed upon it by its particular propagation path through the earth. Only obscure traces of its characteristics as it left its source remain. For this reason, much of seismological research is devoted to unravelling the complexities of the earth's internal structure and to the development of the theory of elastic-wave propagation through nonhomogeneous media. This nonhomogeneity is most severe on land masses where there is a multiplicity of thick crustal layers. On the deep ocean floor, the crustal layers are fewer, thinner, and are believed to be more uniform. Therefore, the theoretical expressions for the distortion introduced by the propagation of seismic signals through this less complex crust are simplified.

But the biggest advantage of underwater seismology from the detection standpoint is that gaps in a land-based detection network, created by vast expanses of ocean, can be filled by using ocean bottom seismometers.

At the start of the AFCRL program, virtually no seismic data existed from the very deep ocean basins. AFCRL began its underwater seismological program two years ago with the construction of two prototype underwater seismometers by Texas Instruments for AFCRL. After initial experiments with these equipments, five more-advanced models were built. These later models, capable of operating to depths of 20,000 feet, were used extensively in a series of tests this year in which over 75 successful emplantments were made and some 500 hours of data were collected on the ocean floor.

Preliminary analysis of the data has led to the following conclusions: (1) while the background noise level is much higher on the ocean floor than on land, the signal level is also higher, so that the signal-to-noise ratio compares favorably with that experienced at land stations; (2) all phases of the seismic-wave train are as clearly defined on the ocean floor as on land; (3) seismic signals recorded on the ocean bottom are richer in high-frequency energy than those recorded on land, and may contain more information regarding the source; and (4) events can be recorded by the ocean-bottom seismometer which are not perceivable by the present network of land stations.

The ocean seismometer packages are rocket-shaped objects about six feet long and about two and a half feet in diameter. The instrumentation is capable of automatically monitoring and recording three components of earth motion and variations in water pressure. A special low-frequency reactance amplifier was built to amplify the signals which are stored on magnetic tape. Eleven hours of data can be recorded, after which time the seismometer is brought to the surface and the data recovered. AFCRL is now considering a projected operational model which would remain unattended on the ocean bottom for 30 days.

EXPLOITING HUMAN VISUAL PROPERTIES IN TV SYSTEMS

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When we watch color television, our eye-brain mechanism does part of the work of color intensification. The designers of color TV took advantage of physiological processes and this permitted a great simplification of circuitry. To present the "full" colors that we think we see on color TV (and that we do in fact see on a motion-picture screen) would pose considerable design difficulties. Comparable use of the properties of the human visual system, however, has not been made in the development of black-and-white television techniques.

AFCRL hopes to exploit the properties of the human visual system in the design of black-and-white TV systems. In the AFCRL approach, the visual system is regarded as an intrinsic part of the over-all system. The approach is one which works backwards from the receiver--the human visual system--into the electronics of television transmission. Those properties of the human visual system

which suggest ways for simplifying the design of electronic hardware will then be identified for more concentrated study.

Behind the AFCRL study is the long-felt need to reduce the band width required to transmit television pictures. Transmission of television pictures demands a very broad band of frequencies--a segment of the radio spectrum covering about 5 megacycles compared to about 10 kilocycles for normal radio broadcasts. By reducing the amount of band width needed to transmit a television picture, more channels would be available on the already crowded radio-frequency spectrum. More important from the Air Force point of view (because of band-width-transmission power relationships) is the fact that band-width reduction will permit the transmission of TV pictures over much greater distances with the same amount of power. This is especially important when transmitters are carried aboard aircraft or space vehicles.

Many attempts by various laboratories have been made to reduce television band width. Most of these use statistical coding, a class of techniques which, if perfected, might result in a 10-to-1 reduction in band width (or power requirements). But statistical coding is often coupled with substantial increases in the complexity of the transmitting or receiving systems. Behind the statistical-coding approach is the fact that most of the TV-picture information transmitted is redundant. There is simply more information transmitted than the human visual system can profitably handle.

The AFCRL study is being conducted on both the theoretical and experimental levels, with the key experimental equipment being special picture-measurement and data-processor facilities. The immediate objective of the work is to define constraints imposed by the physiological and perceptual properties of visual summation and short-term information storage, persistence and retrieval.

The study is not concerned with television-signal properties along scan lines, but with image area properties. Area properties afford a means for taking advantage of the extensive perceptual fusion capability of the visual system in both time and space. By area properties is meant the way in which the image divides itself up into areas of equal brightness. The empirical statistical study of these properties has indicated several interesting picture characteristics from the point of view of human visual perception. First, ordinary pictures apparently have a relatively uniform distribution of brightness values. A high-resolution picture, which consists of about 250,000 brightness-value elements, divides up to about 2500 areas. Relatively few of these 2500 areas are black and white -- most are gray. In addition, nearly half of the area of a typical picture is composed of a very few large areas either black or white. These figures indicate an extensive possibility for more effective utilization of human time-and-space-summation properties in the mode of presentation of television pictures.

grain size alone does not dictate the yield properties of IRON

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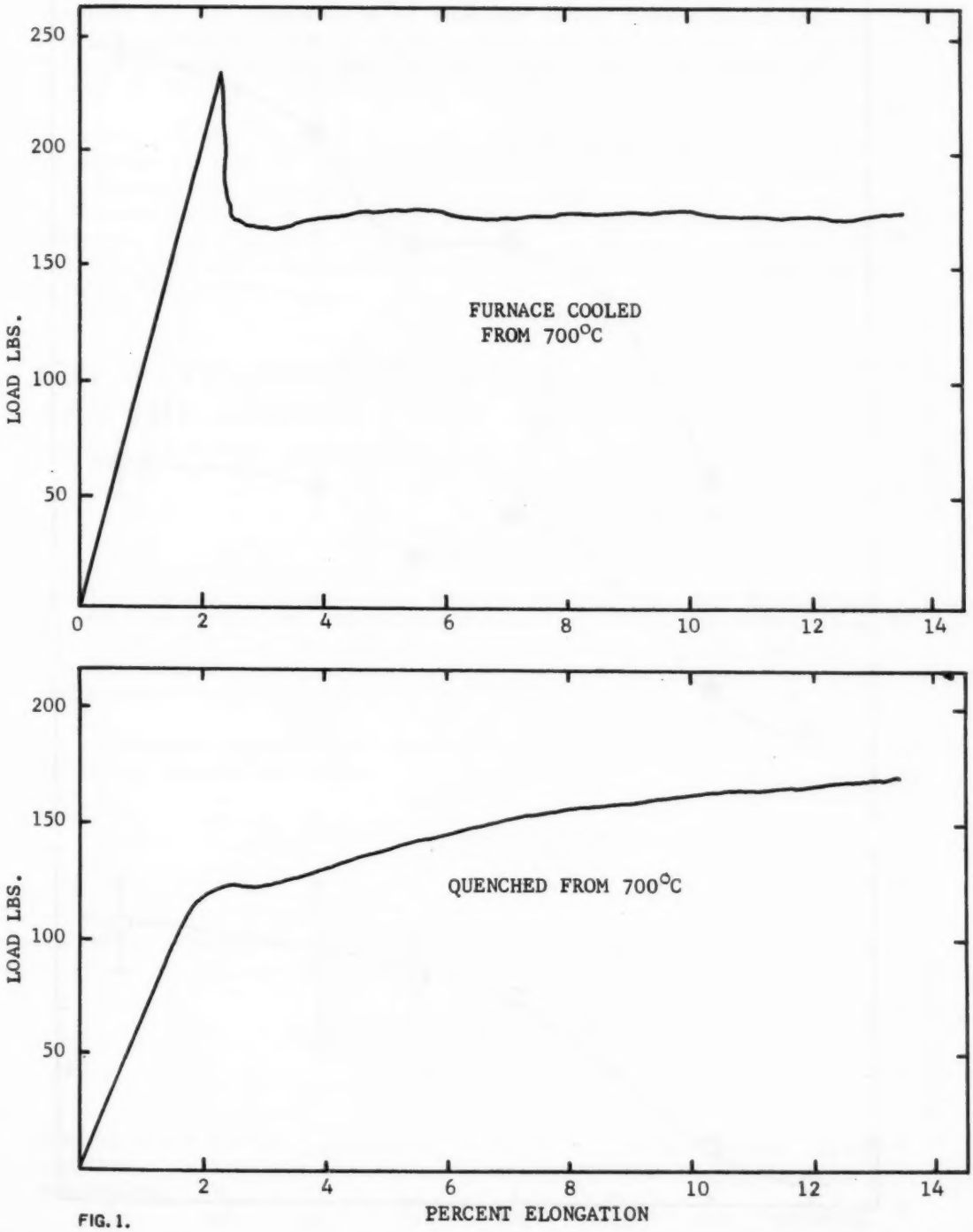
Major R. L. McGAUGHEY, USAF Res , Elgin Watch Co., Rolling Meadows, Ill

Many theoretical analyses of the deformation characteristics of metals depend on a systematic increase in the yield properties as the grain size decreases. This behavior holds true for iron; however, for a given grain size, changes in the yield properties comparable to a two-fold change in grain size can be obtained by varying the cooling rate from an elevated temperature. These observations were made at ARL during an investigation to learn how the nature of the grain boundary and the distribution of small amounts of impurities affected both the onset of plastic deformation and its propagation along the length of a specimen.

Vacuum-melted iron specimens were heated one hour at 700°C, establishing a grain size of about 0.026 mm in diameter. Care was taken to prevent contamination during heating. Immediately following the 700°C treatment, some specimens were water-quenched (a very fast cooling rate) and a few were furnace-cooled (a very slow cooling rate). The differences in the tensile load-elongation curves for specimens with these extremes in cooling rate are shown in Figure 1. The quenched specimen has no upper yield point, a low value of lower yield stress, a short lower yield elongation (or, per cent Lüders strain), and a rapid increase in the initial strain hardening portion of the curve. On the other hand, the furnace-cooled specimen has a large upper yield point, a higher value of lower yield stress, ten per cent Lüders strain, and a shallow strain hardening portion of the curve (after about 12.5 per cent elongation). A series of quenched specimens were re-heated at successively higher temperatures for one hour (followed by furnace cooling) to determine if there is some critical temperature range for the large differences in yield properties observed. These data are shown in Figure 2. It is seen that the yield properties increase with increasing re-heat temperature, and approach the value for the specimens furnace-cooled from 700°C. The minimum in the yield stress curves at 400°C is believed to be a second-order effect.

Since all the specimens had the same composition, the same grain size, and the same thermal and mechanical history, it is believed that the redistribution of impurities during the furnace cooling from 700°C and at various re-heat temperatures for quenched specimens is the factor responsible for the differences in yield properties observed. Examination of all these specimens by optical microscopy indicated that this redistribution of impurities took place mainly by segregation


250
200
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50
LOAD LBS.
FURNACE COOLED
FROM 700°C
0
2
4
6
8
10
12
14
200
150
100
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LOAD LBS.
QUENCHED FROM 700°C
2
4
6
8
10
12
14
PERCENT ELONGATION

FIG. 1.

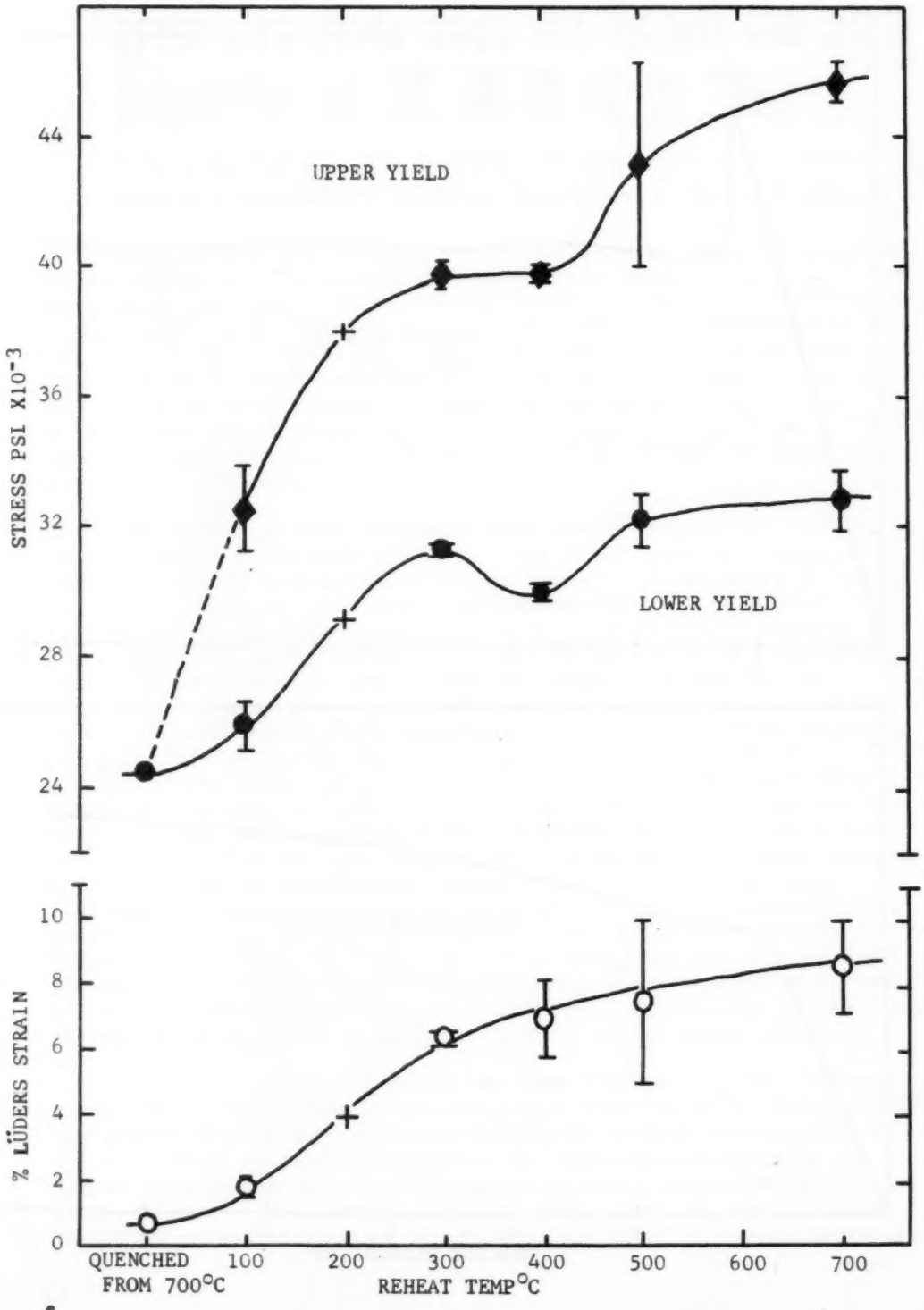
UPPER YIELD
LOWER YIELD
STRESS PSI X10⁻³
44
40
36
32
28
24
% LÜDERS STRAIN
10
8
6
4
2
0
QUENCHED FROM 700°C
100
200
300
400
500
600
700
REHEAT TEMP°C

FIG. 2.

to grain boundaries. Typical grain boundary areas from a quenched specimen and one furnace-cooled from 700°C were then examined by electron-transmission microscopy. These results supported the optical-microscopy observations and clearly showed a large difference in the nature of the grain boundary areas of the two specimens.

Thus, it is inferred that the segregation of impurities to grain boundaries in iron is primarily responsible for the higher values of yield properties shown in Figure 2, and probably controls to a large extent the grain-size dependence of the yield properties normally observed. Further, grain boundaries which have impurity segregation are much more effective barriers to the initiation and propagation of plastic deformation.

GAUSS' TRANSFORMATION AND THE COMPUTATION OF ELLIPTIC INTEGRALS

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In nearly every branch of applied mathematics, one encounters at one time or another the so-called elliptic integrals. They occur, for example, in the calculation or the period of a simple pendulum, the determination of the arc length of the ellipse (whence the name), and numerous other problems.

Elliptic integrals of the "first kind" are defined by the following expression

$$F(\theta,k) = \int_0^\theta \frac{d\phi}{\sqrt{1 - k^2\sin^2\phi}},$$

while those of the "second kind" are defined by

$$E(\theta,k) = \int_0^\theta \sqrt{1 - k^2\sin^2\phi}\, d\phi.$$

Despite their similar appearance, there is no simple relation connecting them. They define a class of transcedents with many interesting properties.

The two parameters, θ and k, on which the above functions depend are usually called, respectively, the amplitude and modulus. In general these are restricted to the ranges $0 \leq \theta \leq \pi/2$ and $0 \leq k < 1$. The special value $\theta = \pi/2$ yields the so-called "complete elliptic integrals" denoted by K(k) and E(k). Thus

$$K(k) = F(\tfrac{\pi}{2}, k)$$

$$E(k) = E(\tfrac{\pi}{2}, k).$$

Because of their wide applications, a simple means of computing these functions is mandatory. Perhaps the most obvious method which would present itself would be to expand the integrands with the aid of the binomial theorem and integrate term by term; but one can easily anticipate that certain difficulties will be encountered when the parameter k is close to unity. In fact, when $\theta = \pi/2$ and $k = 1$, the series for both types are clearly divergent and, hence, very slow convergence can be expected in the vicinity of these values. On the other hand, if k is smaller, the series converge fairly well and can be used without difficulty. For this reason it would be desirous to find a means of expressing the original integrals F and E in terms of similar integrals with a lesser modulus. Fortunately, a remarkable relation discovered some time ago by the German mathematician, Gauss, allows us to do just this. Gauss' transformation goes as follows:

Let $k' = \sqrt{1 - k^2}$, (the so-called "complementary modulus") and define k_1 and θ_1 by

$$k_1 = \frac{1 - k'}{1 + k'}$$

$$\sin\theta_1 = \frac{(1 + k')\sin\theta}{1 + \sqrt{1 - k^2\sin^2\theta}}$$

It is not difficult to see that $k_1 > 0$ and also that $k_1 < k$. Gauss' transformation then consists of the following relations:

$$F(\theta, k) = (1 + k_1)\, F(\theta_1, k_1)$$

$$E(\theta, k) + k'F(\theta, k) = (1 + k')\, E(\theta_1, k_1) + \frac{k^2\sin\theta\cos\theta}{1 + \sqrt{1 - k^2\sin^2\theta}}\,.$$

At first glance these relations appear quite formidable and would seem to be too tedious to be useful. However, they are straightforward, and are of the type which can be easily performed on an automatic computer.

They have the additional assurance of being quite stable numerically. For this reason the transformation can be applied over and over until finlly the original integrals are expressed in terms of ones whose modulus is essentially zero. When this point has been reached, we can obviously set

$$F(0,\theta) = E(0,\theta) = \theta.$$

The transformation is particularly simple when $\theta = \pi/2$, since then

$\theta_1 = \theta_2 = \theta_n = \pi/2$ and we get simply

$$K(k) = (1 + k_1)\, K(k_1)$$

$$E(k) + k'K(k) = (1 + k')E(k,)$$

To illustrate how rapidly the above transformation converges, we take the case where $k = .99$, $\theta = \pi/2$. Starting with $k_o = k = .99$, $k' = .141067360$,

$$k_1 = .752744904 \qquad k_1' = .658312319$$

$$k_2 = .206045434 \qquad k_2' = .978542426$$

$$k_3 = .010845142 \qquad k_3' = .999941190$$

$$k_4 = .000029406 \qquad k_4' = .9999999995$$

$$k_5 = .0000000002 \qquad k_5' = 1.0000000000$$

Hence,

$$K(k_5) = E(k_5) = \pi/2 = 1.570796327$$

and $K(k_4) = 1.570796327$

$$E(k_4) = 1.570796326$$

$$\begin{cases} K(k_3) = 1.000029406K(k_4) = 1.570842518 \\ E(k_3) = 1.999941190E(k_4) - .999941190K(k_3) = 1.570750137. \end{cases}$$

$$\begin{cases} K(k_2) = 1.010845412K(k_3) = 1.587878528 \\ E(k_2) = 1.978542426E(k_3) - .978542426K(k_2) = 1.553989280. \end{cases}$$

$$\begin{cases} K(k_1) = 1.206045434K(k_2) = 1.915053648 \\ E(k_1) = 1.658312319E(k_2) - .658312319K(k_1) = 1.316296159 \end{cases}$$

$$\begin{cases} K(k) = 1.752744904K(k_1) = 3.356600523 \\ E(k) = 1.141067360E(k_1) - .141067360K(k) = 1.028475809 \end{cases}$$

All of the figures in K(k) and E(k) are correct. To obtain comparable accuracy from the power series would require about 200 terms.

ION-WAVE RESONANCE AND PLASMA INSTABILITY IN A CESIUM DISCHARGE

Lt. JOHN A. DECKER, JR., USAF, *Plasma Physics Research Laboratory*, ARL

Intense interest in such potential engineering applications of plasma technology as electrical-rocket propulsion, controlled thermonuclear - fusion reactors, and re-entry telecommunications "black-out" has spurred recent cesium-vapor gas discharge research. The low ionization potential and high atomic mass of cesium offer substantial experimental advantages to the plasma physicist working in such areas as plasma instability, plasma oscillations and wave propagation.

A program was established as part of the author's PhD research at the University of Cambridge, Cambridge, England, (and is currently being continued and extended in the Plasma Physics Research Laboratory at ARL), to study ion-wave oscillations and plasma instabilities in a low-pressure cesium discharge in axial magnetic fields up to 5000 gauss. Small cesium plasma tubes were built, each approximately one meter long by five cm in diameter, which incorporated externally heated cathodes designed for operation at d-c currents up to one ampere. All currents and voltages were continuously recorded and monitored by oscilloscopes, and conditions within the plasma were studied by floating electrostatic probes and by Langmuir probes; the discharge visible spectrum and visual appearance were recorded photographically; in addition, external windings for pulsed fields and magnetic-disturbance detectors were provided.

For certain discharge conditions, the usually-random electrical noise within the plasma became coherent: one frequency predominated, and the oscillations could be observed directly on an oscilloscope without the use of any frequency-selective detection apparatus. Observed frequencies varied from several hundred cps to several kcs, and were broadly independent of magnetic field for fields over 1000 gauss; no coherent oscillations were observed, however, at zero

magnetic field. Similar (but noncoherent) oscillations have been observed for the zero-magnetic-field case since the early 1920's, and were interpreted in terms of electroacoustic "ion waves" by Tonks and Langmuir in 1929.

It was postulated that the observed oscillations were ion waves in resonance with the discharge tube length (in a manner somewhat analogous to the generation of tones in an organ pipe). Resonant frequencies were computed from the "dispersion equation" (relating wave length to frequency) given by Tonks and Langmuir (as well as theoretical discharge tube frequencies computed for acoustic resonance, magnetohydrodynamic resonance, ion gyrofrequency instability, and the Kadomtsev helical plasma instability), and compared with observed oscillation frequencies as a function of the discharge parameters. Agreement with experiment was better than the experimental uncertainty for the ion-wave resonance theory, while no other theory showed even approximate agreement: observed coherent oscillations were therefore identified as electroacoustic "ion waves" in resonance with the discharge tube length.

In addition, the discharge extinguished if either the current or magnetic field was increased above critical values which were complicated functions of the operating parameters. This was invariably preceded by a rapid growth in ion-wave amplitude and in the amplitude of "hash" in the current and plasma electric field; the time from the first oscillation growth to discharge-extinguishing varied from about 1/10th second up to some tens of seconds. As photographs of the discharge indicated the presence of highly asymmetrical-- probably helical-- perturbations in the plasma immediately prior to the extinguishing of the discharge, it was postulated that the observed instability might be of the helical type suggested by Kadomtsev and Nedospasov. This involves a growing helical displacement of the electrons and ions in the plasma "driven" by the discharge current and the magnetic field, and damped by electrostatic forces and the "frictional" effects of neutral gas molecules.

An analysis based on the mathematical formulation of Johnson and Jerde was performed after evaluating the relative effect of neutrals on the ions and electrons in our plasma from kinetic theory; the resulting stability-balance equations were then solved on the Cambridge University Mathematical Laboratory's EDSAC II high-speed digital computer to obtain the critical electric field and frequency on the stability boundary as a function of applied magnetic field. Stability analyses were also made using theories of ion-wave instability, "sheath instability," electron "runaway," and magnetohydrodynamic-wave instability. Computed instability regimes were then compared with observed instability onset data as a function of the discharge parameters.

Unfortunately, no theory predicted accurately the extinguishing of the discharge (a situation at least partially due to extreme "scatter" in the data points); the helical instability theory did, how-

ever, reproduce the general inverse variation of critical electric field with magnetic field shown by the experimental data. This was true for no other theory. It was tentatively concluded that the observed instability probably is some type of helical plasma instability similar to that proposed by Kadomtsev and Nedospasov. An accurate instability model, however, should include the observed strong correlation between instability onset and rapid ion-wave growth; work is proceeding at present on this problem.

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selective blocking of BIOLOGICAL DEVELOPMENT

Captain B. D. STOLLAR, USAF, *Biological Sciences Division*, AFOSR

As soon as we know where things go, we begin to ask questions about what makes them go there. In terms of biochemistry, we have learned many of the reaction pathways along which biochemical materials pass. Now the burning questions concern the controls which, under varying conditions, block some pathways and open the gates to others.

In terms of developmental biology, careful studies have been made of the stages through which organisms pass, in changing from a single cell to a complex structure of many kinds of cells. We know that at crucial stages the formation of one kind of cell or tissue becomes rapid, but that later it is slowed down and other types are formed more rapidly. Now we are beginning to ask how the various stages are turned on and off.

All these processes have to be perfectly timed and coordinated with each other; there is no chance to go back and make up for a missed step. The results of mismanagement in the coordination process may be gross deformities. Widely known examples are those which were caused by the drug thalidomide. This drug blocked the formation of limb-bud tissues in the development of limbs. Some biochemical steps determining this phase of development were selectively obstructed.

In experimental studies, selective blocking agents can provide information about normal controls. Dr. J. Brachet, an AFOSR grantee

at the Free University of Brussels, has been studying one type of chemical blockage of development. He has found that certain sulfur-containing compounds (mercaptoethanol, lipoic acid, and dithiodiglycol) prevent a crucial stage of nervous-system development; this was observed in amphibian and chick embryos.

In one case, the blocked structural change was accompanied by at least one biochemical obstruction. A conversion required for the formation of some of the constituents of DNA (the central genetic material of the cell) was prevented. In another case, the agent causing the block in nervous-system development actually sped up the above-mentioned conversion. While these two agents acted in opposite directions, they both affected central processes involved in DNA formation and could, therefore, be acting by throwing this part of the delicate coordination out of balance. It may turn out, of course, that the biochemical effects observed so far are not the only critical ones.

Studies with agents which specifically block developmental steps are just beginning. In the past thirty years, analogous studies with specific blockers of biochemical reactions have provided many keys with which to unlock the doors to knowledge about biochemical-reaction pathways. Further studies will unlock the doors to both biochemical- and developmental-control boxes at the crossroads. The results will be of benefit not only to the medical profession in its fight against developmental deformities, but will also enlighten us concerning the most sophisticated system in existence for the programming and utilization of stored information, a model for technologists. Further, these results will help us to recognize and counteract potentially dangerous exposure to chemicals which can affect biological-control systems.

AFCRL note

Transmissions from the TIROS-8 weather satellite launched by NASA on 21 December 1963 are being received at AFCRL by APT (Automatic Picture Transmission) equipment installed during the past six months. The AFCRL installation is one of 20 Air Force stations capable of printing facsimiles of pictures taken by the satellite as it passes overhead. Each photograph is of an area covering more than 670,000 square miles. A command camera system of the type used on previous weather satellites, also on board, can take pictures, store them on tape, and then transmit them as the satellite passes over one of three read-out stations located at Point Mugu, California; Wallops Island, Virginia; and Fairbanks, Alaska. These pictures are then transferred to 35-mm film strips and supplied to interested agencies. The TIROS-8 has an apogee of approximately 473 miles, and its perigee is about 435 miles. Thomas Keegan of AFCRL is in charge of the program. (Meteorology Laboratory, AFCRL)

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